

## AGRONOMIC PERFORMANCE OF COTTON AND SOYBEAN CULTIVATED UNDER DIFFERENT COVER CROPS AND LIME AND GYPSUM DOSES

### DESEMPENHO AGRONÔMICO DO ALGODÃO E DA SOJA CULTIVADOS SOB DIFERENTES PLANTAS DE COBERTURA E DOSES DE CALCÁRIO E GESSO

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**ABSTRACT:** Soil management with the use of lime and agricultural gypsum can influence the development and yield of cotton and soybean crops. The use of cover crops avoids soil degradation and ensures nutrient cycling on the soil surface. In most cultivated species, the application of lime and agricultural gypsum provides corrections in the sub-surface soil, keeping the nutrients available. This study aimed to (i) verify whether cotton and soybean cultivated in succession to cover crops affect its agronomic performance and (ii) evaluate the influence of lime and gypsum doses on the agronomic performance of these crops. Two experiments were performed. The first experiment consisted of cotton cultivated in the off-season, and the second, of soybean cultivated in the regular season. The experiment was carried out under three plant residues (*Urochloa ruziziensis*, *Pennisetum glaucum*, and fallow area), combined with lime and gypsum doses. The experiment consisted of a completely randomized block design with four replications. For the cotton crop, only the gypsum doses influenced the variables plant height, initial and final population, and yield. Cover crops did not influence the agronomic performance of cotton and soybeans. The increase of lime doses resulted in a linear increase in cotton and soybean yield. The highest gypsum dose improved the agronomic performance of cotton plants; however, it only influenced the height of soybean plants.

**KEYWORDS:** Plant residues. *Glycine max.* *Gossipium hirsutum.* Green manure.

## INTRODUCTION

In the no-tillage system (NTS), surface and subsurface calcium deficiency may be linked to aluminum toxicity. In the Brazilian Cerrado, the aluminum toxicity results in soil acidity, which affects the yield of the cultivated species (PRADO et al., 2003). The soil calcium content in the Brazilian agricultural area is lower than 0.4 cmolc dm<sup>-3</sup>, and the aluminum saturation is higher than 10% in the subsurface. Thus, about 90% of the agricultural area is under these conditions, which hinders the development of plants roots and damages the nutrients and water absorption by plants (SOUZA, LOBATO; REIN, 2001).

The effect of liming in reducing soil acidity is quite slow since it is limited to the application area. When applied to the surface, liming does not guarantee the subsurface correction and requires the leaching of the carbonates to guarantee its efficiency in the deeper layers for better yield (BLUM et al., 2013). Therefore, agricultural gypsum, which presents higher mobility in the soil and acts as a conditioner, provides calcium (Ca<sup>2+</sup>) and sulfur (SO<sub>4</sub><sup>2-</sup>) in solution and guarantees the leaching of

nutrients to the deeper soil layers, and reduces the aluminum toxicity in the subsurface (CAIRES et al., 2006).

The use of cover crops in a crop rotation system may be advantageous for soil properties and improve nutrient absorption and translocation efficiency (SANTOS et al., 2004; ZOTARRELI et al., 2012). Cover crops can increase crop yield in soil management in a more sustainable and economical way. This fact is due to better nutrient cycling and soil chemical, physical, and biological conditions (CARVALHO et al., 2019). However, the decomposition rate of plant residues in the Brazilian Cerrado is high owing to climatic characteristics, such as high temperatures and high humidity, which cause faster degradation (CARVALHO et al., 2011).

The decomposition of the plant material can affect nutrients availability, such as N, P, K, Mg, and S, and increase soil pH, generating organic compounds such as fulvic and humic acids. These compounds are crucial in the alleviation of stresses, development of the root system, and synthesis of enzymes. However, in the case of NTS, these compounds may not be detected in the short-term subsurface acidity mitigation (PAVINATO;

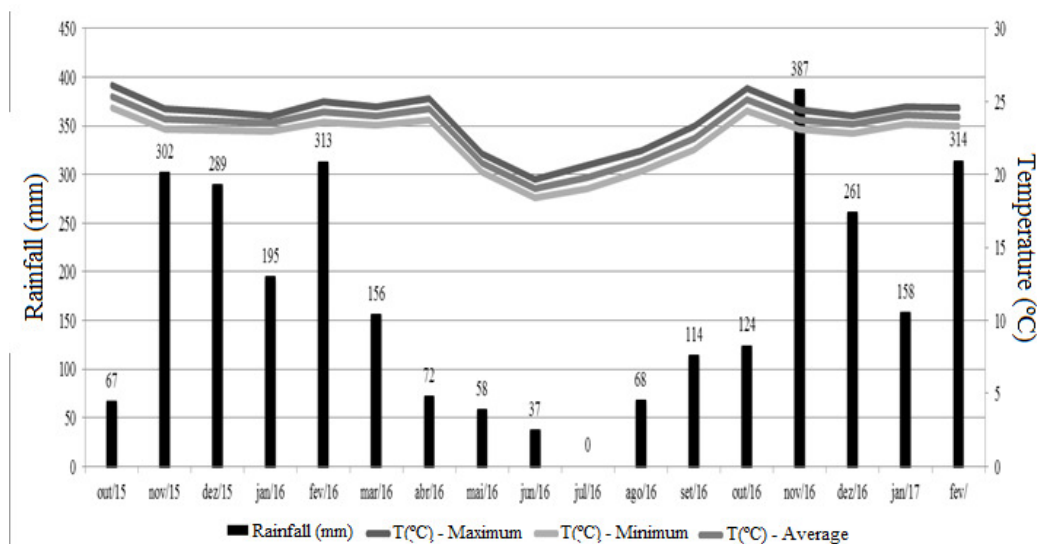
ROSOLEM, 2008; CAIRES et al., 2008a). In this context, liming is an ideal management strategy to reduce the exchangeable Al and Mn in the soil. Nevertheless, when applied without incorporation, soil correction can be limited while in the soil surface. Thus, the application of agricultural gypsum gives necessary contribution for the satisfactory crop development.

The Cerrado soils are low fertile and highly acid with high aluminum content. Therefore, this study aimed to evaluate the agronomic performance of the soybean crop in succession to cover crops with the superficial application of lime and gypsum doses.

## MATERIAL AND METHODS

The experiments were carried out in the experimental area of the Centro de pesquisas da Fundação de Apoio a Pesquisa Agropecuária de Chapadão do Sul – FUNDAÇÃO CHAPADÃO, in the municipality of Chapadão do Sul, MS (18°41'33 "S, 52°40' 45 " W and altitude of 810 m).

The climate of the region is wet and dry (Aw), according to Koppen, with well-defined seasons, characterized by rainy summer and dry winter. The average annual temperature in the coldest month is higher than 18°C, ranging between 13°C and 28°C between seasons, with average annual rainfall of 1.850 mm, and average annual relative humidity of 64.8% (Castro et al., 2012). Rainfall and air temperature data were recorded during the experimental period. (Figure 1).



**Figure 1.** Rainfall and air temperatures during the experimental period. Source: INMET.

The soil of the experimental area was classified as Dystrophic Red Latosol, based on the methodology of Embrapa (2013). The classification is obtained by evaluating the morphological, physical, chemical, and mineralogical data of the profile that represents the soil. Environmental aspects are also taken into account, such as climate,

vegetation, relief, soil external characteristics, water conditions, and source material. A soil sample was collected before the experiment installation, revealing the chemical analysis (Table 1) and the granulometric composition (46% clay, 51.5% sand, and 2.5% silt), evaluated in the 0.0-0.4 m layer.

**Table 1.** Soil chemical analysis before the experiment installation.

Depth	pH	Ca	Mg	Al	H+Al	K	P(res)	S	O.M	CEC	V	m
m	CaCl <sub>2</sub>	-----cmol <sub>c</sub> dm <sup>-3</sup> -----				-----mg dm <sup>-3</sup> ---		gdm <sup>3</sup>	cmol <sub>c</sub> dm <sup>3</sup>	----%----		
0-0.2	4.2	2.0	0.3	0.3	5.5	157	37.3	7.7	36.9	8.3	33.5	11.6
0.2-0.4	4.3	1.3	0.2	0.2	5.2	94	5.70	15.8	24.0	6.9	25.1	9.8
Depth	B	Cu		Fe		Mn		Zn				
m	-----mg dm <sup>-3</sup> -----											
0-0.2	0.14	1.30		44.0		16.4		5.2				

The experiment consisted of a completely randomized block design with four replications, in a split-plot scheme. The main plot consisted of two cover crops (*Urochloa ruziziensis*, *Pennisetum glaucum*) and one fallow treatment; the subplot consisted of agricultural gypsum (0, 2300, and 4600 kg ha<sup>-1</sup>); and the sub-sub-plot consisted of lime doses (0, 2000, 4000, and 6000 kg ha<sup>-1</sup>).

The experiment was carried out in the NTS area on September 15, 2015, with the application of lime, with 85% TNRP (total neutralization relative power). The application of agricultural gypsum (October 26, 2015) aimed at increasing the base saturation to 50%, according to the recommendation of Souza and Lobato (2005). Lime and gypsum were applied to the surface without incorporation. Table 1 shows the soil chemical analysis of the experimental area before the experiment installation.

The increase the base saturation was the method used to calculate the need for liming (Rajj et al., 1996). The method of Sousa and Lobato was used to determine the amount of agricultural gypsum to be applied. The soil clay content was determined by the gypsum dose of 2.3 Mg ha<sup>-1</sup>, the gypsum formulation used was 18% CaO and 15% of S.

Cover crops were sown on October 8, 2015, with 5 and 15 kg ha<sup>-1</sup> of seeds of *U. ruziziensis* and *P. glaucum* (cv ADR 300), respectively, using mismatched discs, spaced at 0.17 m between rows. With the aid of a horizontal plant residue crusher (Triton), the cover crops were managed on January 15, 2016. On January 24, 2016, the material was dried using glyphosate (1.98 kg ha<sup>-1</sup> of a.i.) and carfentrazone-ethyl (20 g ha<sup>-1</sup> of a.i.).

Afterwards, the cotton crop was implanted on February 4, 2016, obtaining a cycle of 190 days. The cultivar FM975WS (medium size, high fiber yield, great productive potential in the market) was used in the experiment. Base fertilization consisted of 120 kg ha<sup>-1</sup> of potassium, which was applied using a fertilizer seeder, with a front cutting disk and a fertilizer distribution system, spaced at 0.90 m between rows, and with seed density of nine seeds per meter.

The cotton crop had three plants per sub-subplot evaluated for plant height (measured from the ground to the base of the last leaf insertion), weight of thirty bolls (measured with a precision digital scale) and yield in kg ha<sup>-1</sup>. The crop was harvested on August 10, 2016.

The soybean crop was installed on October 18, 2016, with cultivar NA 5909 (undetermined growth habit, medium size, maturity group 5.9,

intermediate fertility requirement). Base fertilization consisted of 150 kg ha<sup>-1</sup> MAP (11% N – 52% P<sub>2</sub>O<sub>5</sub> – 00% K<sub>2</sub>O), which was applied using a fertilizer-sowing, with a front cutting disk and a fertilizer distribution system, spaced at 0.45 m between rows, and with seed density of 22 seeds per meter.

The soybean crop had three plants per sub-subplot evaluated for plant height (measured from the ground to the base of the last leaf insertion), insertion of the first pod (measured from the ground to the base of the first pod insertion), weight of one hundred grains (measured with a precision digital scale), and grain yield. Grain yield was obtained by threshing and weighing the grains from all pods harvested in the useful area of the sub-subplots, which was converted to kg ha<sup>-1</sup>.

Data were subject to analysis of variance, followed by the means comparison of gypsum doses and cover crops by the Tukey's test (P < 0.05). Polynomial regression analysis was used for lime doses in the Sisvar software (FERREIRA, 2011).

## RESULTS AND DISCUSSION

### Cotton agronomic performance

Table 2 shows the summary of the analysis of variance for the cotton variables. The cover crop did not influence the cotton agronomic performance. Some factors hinder the yield of the crop cultivated in succession to cover crops. In the Brazilian Cerrado, the dry spell is characteristic in the rainy season; cover crops are sown in the spring/summer, which can reduce in productive potential (BURLE et al., 2006; CARVALHO et al., 2008). Thus, the low rainfall in the month of treatment implantation (October) may have contributed to the present results.

The gypsum application influenced plant height, initial stand, final stand, and cotton yield (Table 3). Similar results for cotton yield were observed by Sadic et al. (2003), who reported an increase in this variable when compared with the treatment without agricultural gypsum application.

The application of agricultural gypsum increases sulfur and calcium availability, and thus reduces the levels of toxic Al in the soil, favoring nutrient absorption (Sousa et al., 2005). This significant growth occurs due to the excessive availability of calcium and other nutrients, which improve soil fertility. Moreover, the gypsum application increases the root growth and carries nutrients to deeper layers (CAIRES et al., 2004 and 2008), and thus influences the crop development.

**Table 2.** Summary of analysis of variance for plant height (PH), initial plant stand (IS), final plant stand (FS), weight of thirty bolls (WTB), and cotton yield (CY) of cotton plants cultivated under different cover crops and lime and gypsum doses.

SV	DF	PH	IS	FS	WTB	CY
		Mean Square				
Block	3	1018.24*	392.01*	668.33*	469.07 <sup>ns</sup>	14411.05 <sup>ns</sup>
Cover (C)	2	105.11 <sup>ns</sup>	26.30 <sup>ns</sup>	59.14 <sup>ns</sup>	16.75 <sup>ns</sup>	5095.83 <sup>ns</sup>
Gypsum (G)	2	1162.67*	290.73 <sup>ns</sup>	654.04*	70.75 <sup>ns</sup>	11294.39*
Lime (L)	3	273.17 <sup>ns</sup>	68.23 <sup>ns</sup>	153.61 <sup>ns</sup>	537.07*	33988.20*
C x G	4	9.37 <sup>ns</sup>	2.34 <sup>ns</sup>	5.25 <sup>ns</sup>	267.25 <sup>ns</sup>	2267.34 <sup>ns</sup>
C x L	6	9.49 <sup>ns</sup>	2.36 <sup>ns</sup>	5.33 <sup>ns</sup>	341.38 <sup>ns</sup>	587.57 <sup>ns</sup>
G x L	6	72.73 <sup>ns</sup>	18.18 <sup>ns</sup>	40.91 <sup>ns</sup>	1196.60*	1775.29 <sup>ns</sup>
C x G x L	12	16.15 <sup>ns</sup>	4.03 <sup>ns</sup>	9.08 <sup>ns</sup>	201.32 <sup>ns</sup>	893.58 <sup>ns</sup>
Error 1	6	76.11	19.03	42.81	217.26	9512.64
Error 2	12	28.98	7.25	16.31	207.37	924.34
Error 3	37	37.11	9.25	20.87	188.83	862.11
CV 1 (%)		11.02	10.68	10.90	13.72	59.04
CV 2 (%)		6.80	6.59	6.73	13.41	18.50
CV 3 (%)		7.69	7.46	7.61	12.79	17.77
Mean		79.19	40.84	60.01	107.42	165.20

SV: source of variation; CV: coefficient of variation; DF: degrees of freedom; ns and \*: not significance and significance at 5% de probability by F-test, respectively.

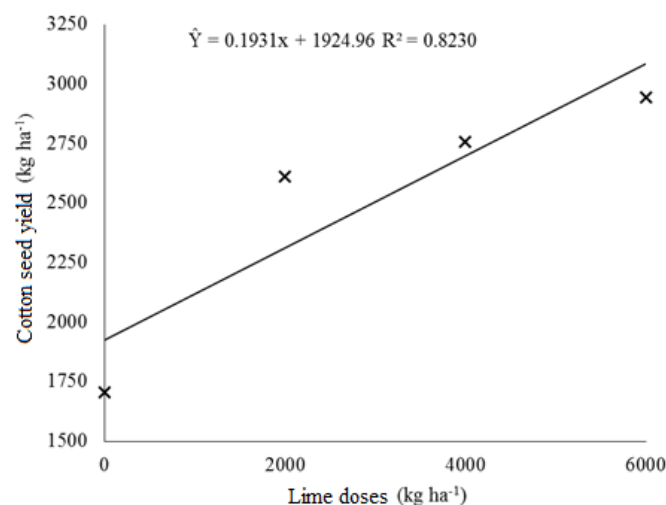
**Table 3.** Means comparisons for the variables plant height (PH), initial stand (IS), final stand (FS), and cotton yield under different gypsum doses.

Gypsum	PH	IS	FS	CY
0	73.68 b	38.09 b	55.86 b	2254.92 b
2300	83.15 a	42.83 a	62.99 a	2527.80 ab
4600	80.74 a	41.62 a	61.18 a	2730.41 a

Means followed by different lowercase letters in the same column differ from each other by the Tukey's test at 5% probability.

Lime doses affected cotton yield, obtained by a linear regression, where the increase of the lime doses increased significantly crop yield (Figure 2). Silva et al. (1987b, 1995, 1997), with the repetition

of liming in long-term trials, also observed a close relationship between cotton production and soil subsurface acidity correction.

**Figure 2.** Cotton seed yield in relation to lime doses.

### Soybean agronomic performance

Table 4 shows the summary of the analysis of variance for the soybean variables. The cover crops did not influence the soybean agronomic performance. The climate of the Brazilian Cerrado provides faster decomposition (as in the case of *Brachiaria ruziziensis*, which has lower lignin

content) and faster nutrient cycling, not providing a positive increase in the subsequent species. Conversely, *Pennisetum glaucum* presents higher lignin content, which guarantees better soil coverage (CARVALHO et al., 2008, 2009, 2011). Thus, the cover crops must be monitored in other seasons for the generalization of these results.

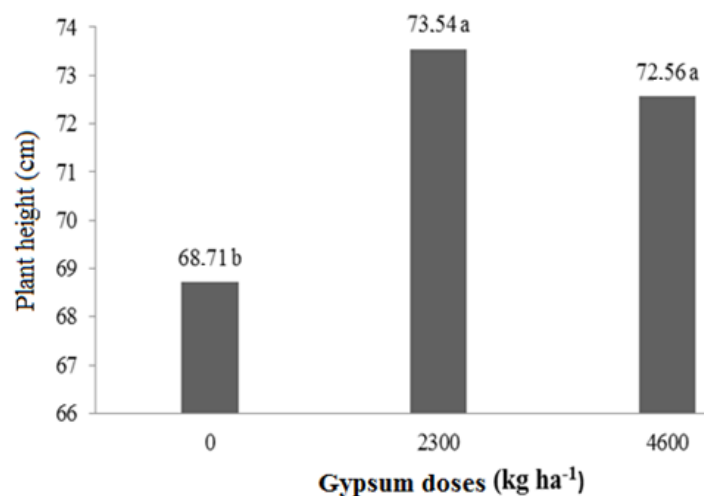
**Table 4.** Summary of the analysis of variance for plant height (PH), insertion of first pod (IFP), weight of one hundred grains (WHG), and grain yield (GY) of soybean cultivated under different cover crops and lime and gypsum doses.

SV	DF	PH	IFP	WHG	GY
Block	3	270.05*	242.12*	1.39 <sup>ns</sup>	677218.73 <sup>ns</sup>
Cover (C)	2	114.72 <sup>ns</sup>	22.67 <sup>ns</sup>	0.58 <sup>ns</sup>	1341409.45 <sup>ns</sup>
Gypsum (G)	2	312.39*	0.13 <sup>ns</sup>	0.41 <sup>ns</sup>	36761.33 <sup>ns</sup>
Lime (L)	3	77.59 <sup>ns</sup>	6.01 <sup>ns</sup>	6.52*	1139960.01*
C x G	4	100.43 <sup>ns</sup>	0.99 <sup>ns</sup>	0.09 <sup>ns</sup>	67923.95 <sup>ns</sup>
C x L	6	8.15 <sup>ns</sup>	10.33 <sup>ns</sup>	0.24 <sup>ns</sup>	221379.88 <sup>ns</sup>
G x L	6	50.59 <sup>ns</sup>	5.12 <sup>ns</sup>	0.35 <sup>ns</sup>	59526.76 <sup>ns</sup>
C x G x L	12	32.42 <sup>ns</sup>	3.40 <sup>ns</sup>	0.34 <sup>ns</sup>	147206.32 <sup>ns</sup>
Error 1	6	28.04	6.00	0.42	251966.73
Error 2	12	27.21	2.45	0.06	81861.34
Error 3	37	27.24	7.45	0.24	140547.58
CV 1 (%)		7.39	16.27	3.57	9.77
CV 2 (%)		7.28	10.39	1.32	5.57
CV 3 (%)		7.29	18.12	2.71	7.30
Mean		71.61	15.06	18.26	5136.99

SV: source of variation; CV: coefficient of variation; DF: degrees of freedom; ns and \*: not significance and significance at 5% de probability by F-test, respectively.

The doses of agricultural gypsum influenced only plant height in soybean plants (Table 4). The application of the recommended agricultural gypsum dose provided the greatest plant height (Figure 3). Other researches verified that the

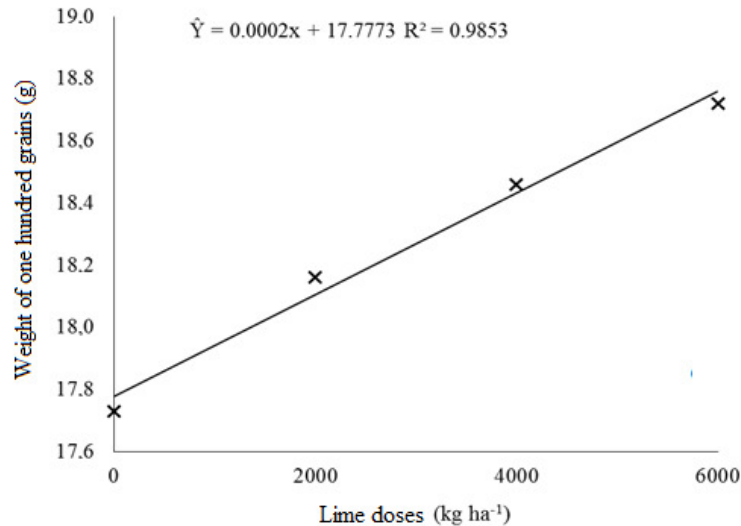
application of gypsum did not increase soybean grain yield (CAIRES et al., 2003 and 2006; NOGUEIRA; MELO 2003; MASCHIETTO 2009), corroborating the results of the present study.



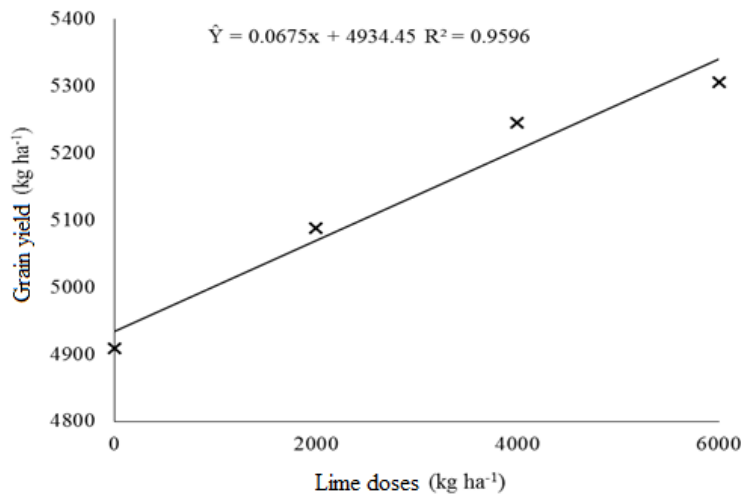
**Figure 3.** Plant height of soybean in function of agricultural gypsum doses.

The lime doses influenced only the weight of one hundred grains and the grain yield of the soybean crop (Table 2). A linear increase was detected for these variables in function of the increase of lime doses (Figures 4 and 5, respectively). Quaggio et al., (1993), when incorporating lime in the first cultivation year,

verified improvement in the conditions in the development of the crop, such as the root environment. The lime application improves the chemical soil condition by increasing the pH and reducing the potential acidity, which results in positive growth in the root development and plant absorption, and thus improves soil yield.



**Figure 4.** Weight of one hundred grains of the soybean in relation to the lime doses.



**Figure 5.** Grain yield of soybean in relation to lime doses.

Tomelero et al. (2016) stated that the application of lime increases soybean yield. The authors also affirmed that lime increases soybean nodulation due to soil pH correction, which is favorable for nodulation. No interactions were detected between the factors studied for both the agronomic performance of cotton and soybean crops (Tables 2 and 3). These results allow recommending the cultivation of cotton (off-season) and soybean under fallow and the application of the highest gypsum and lime doses to obtain the highest yield in these crops.

## CONCLUSIONS

Cover crops do not influence the agronomic performance of cotton and soybean crops.

The increase of lime doses resulted in a linear increase in cotton and soybean yield.

The application of the highest agricultural gypsum dose improved the agronomic performance of cotton, but only influenced plant height in the soybean crop.

**RESUMO:** O manejo do solo com o uso de calcário e gesso agrícola pode influenciar o desenvolvimento e produtividade das culturas de algodão e soja. O uso de culturas de cobertura evita a degradação do solo e garante a ciclagem de nutrientes na superfície do solo. Na maioria das espécies cultivadas, a aplicação de cal e gesso agrícola fornece correções no solo subsuperficial, mantendo os nutrientes disponíveis. Este estudo objetivou (i) verificar se o algodão e a soja cultivados em sucessão à cobertura vegetal afeta seu desempenho agrônômico e (ii) avaliar a influência das doses de calcário e gesso no desempenho agrônômico dessas culturas. Dois experimentos foram realizados. O primeiro experimento consistiu de algodão cultivado no período de entressafra e o segundo de soja cultivada na estação regular. O experimento foi conduzido sob três resíduos vegetais (*Urochloa ruziziensis*, *Pennisetum glaucum* e pousio), combinados com doses de cal e gipsita. O experimento consistiu de um delineamento de blocos ao acaso, com quatro repetições. Para a cultura do algodoeiro, apenas as doses de gesso influenciaram as variáveis altura da planta, população inicial e final e produtividade. As culturas de cobertura não influenciaram o desempenho agrônômico do algodão e da soja. O aumento das doses de calcário resultou em um aumento linear no rendimento de algodão e soja. A maior dose de gesso melhorou o desempenho agrônômico das plantas de algodão; no entanto, influenciou apenas a altura das plantas de soja.

**PALAVRAS-CHAVE:** Resíduos vegetais. *Glycine max*. *Gossipium hirsutum*. Adubo verde.

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